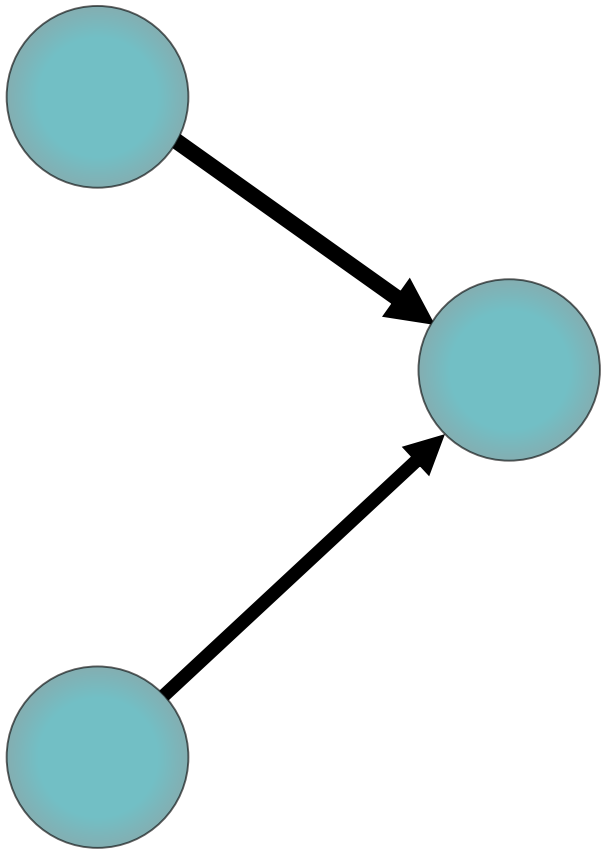
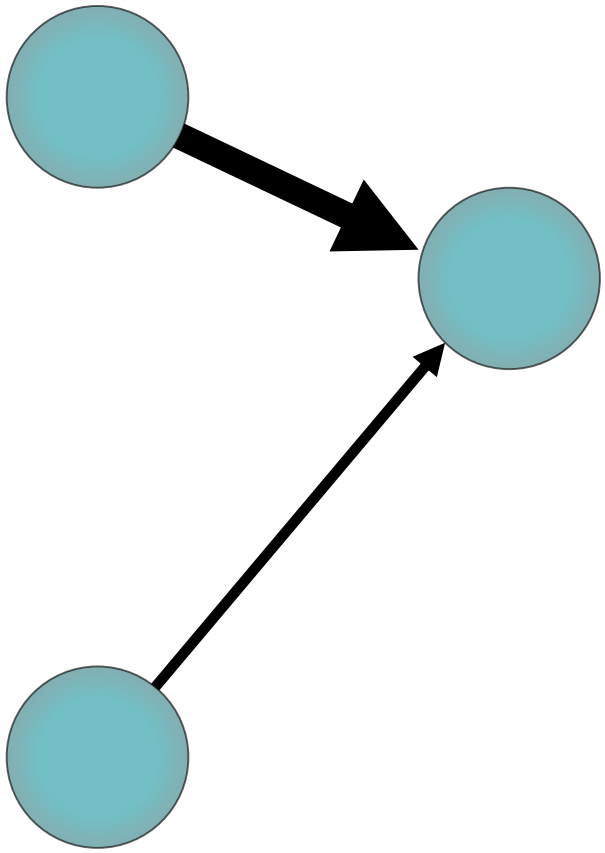
Effectively Capturing Attention Using the Capture Effect

Michael König
Roger Wattenhofer

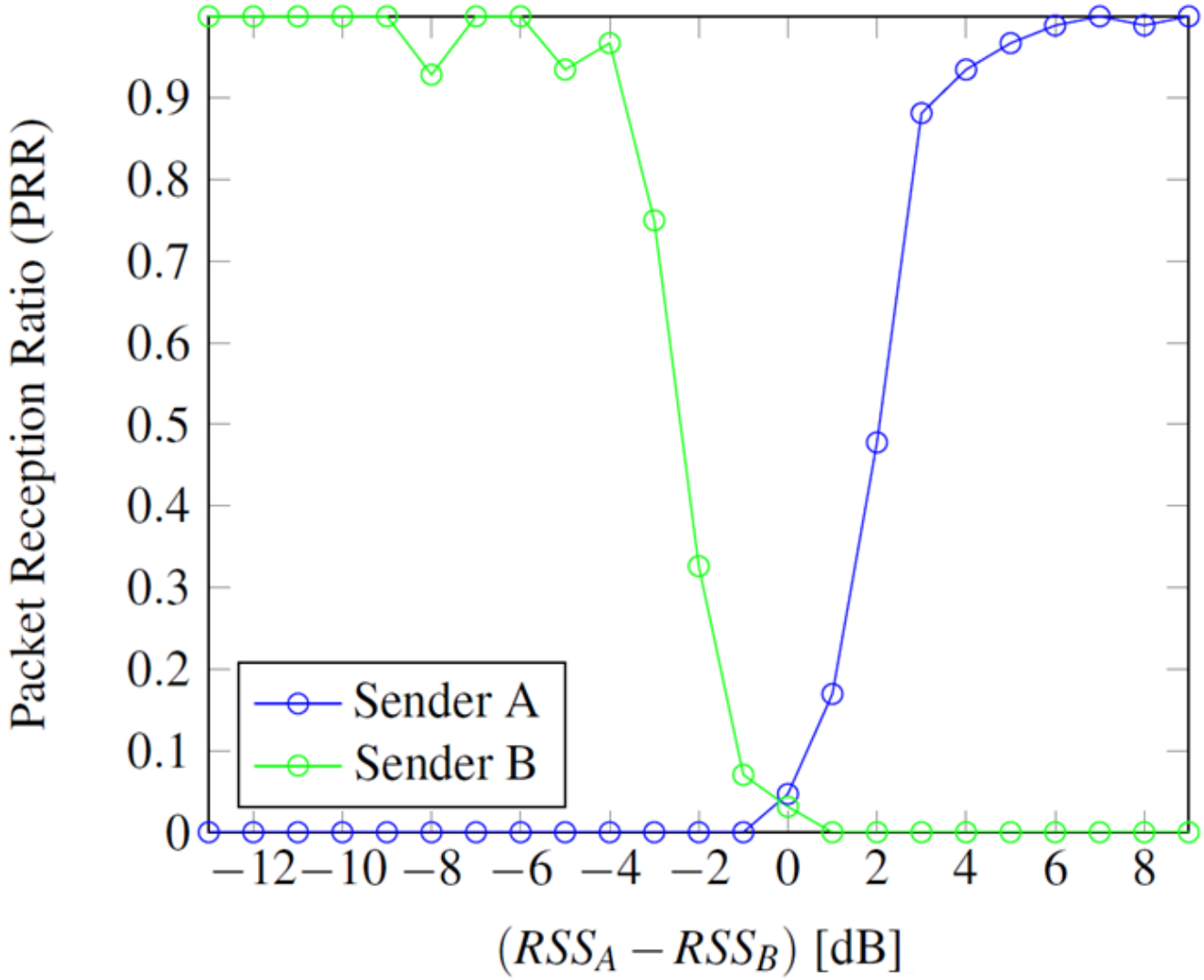
The Capture Effect



The Capture Effect

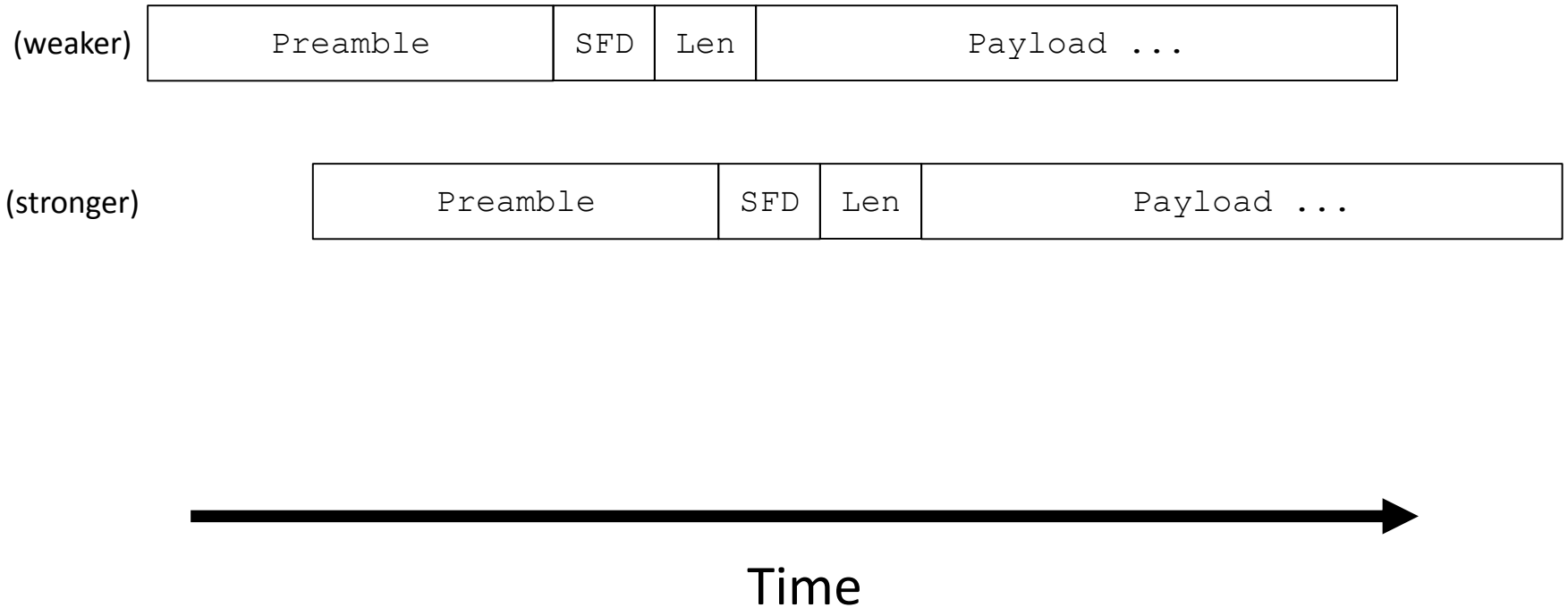


The Capture Effect – Power Difference

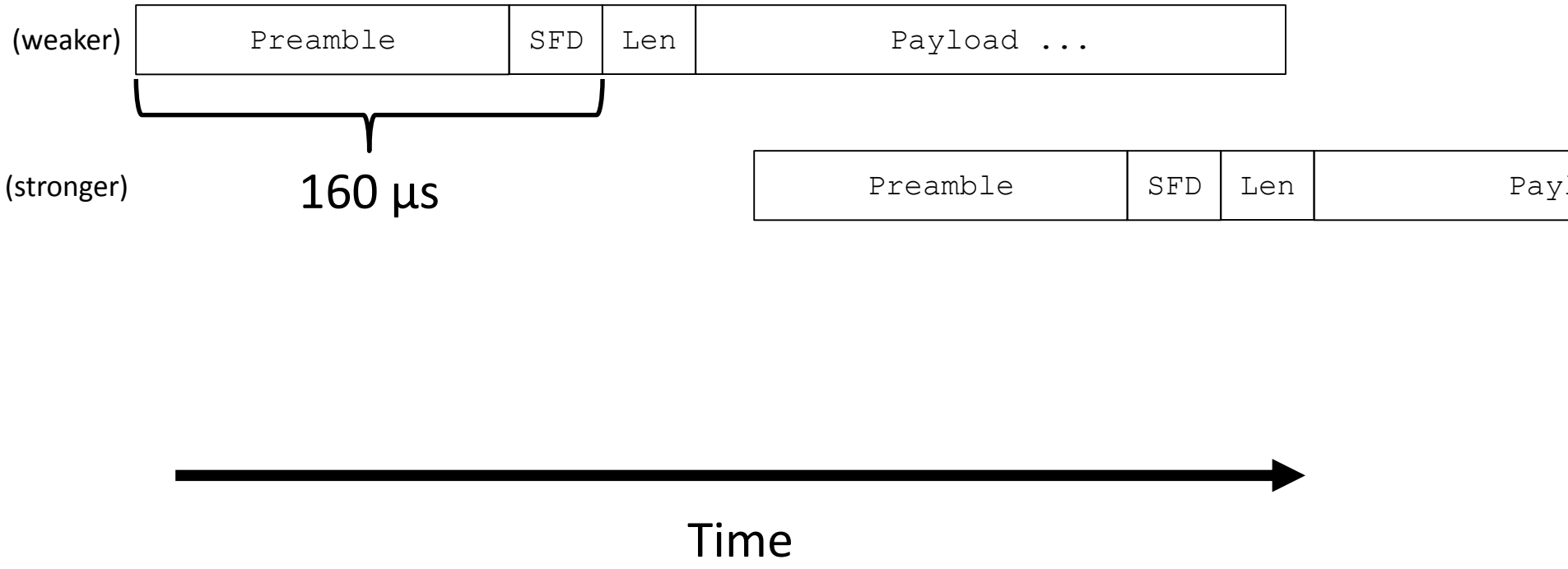


["Sharing a Medium Between Concurrent Protocols Without Overhead Using the Capture Effect", 2016]

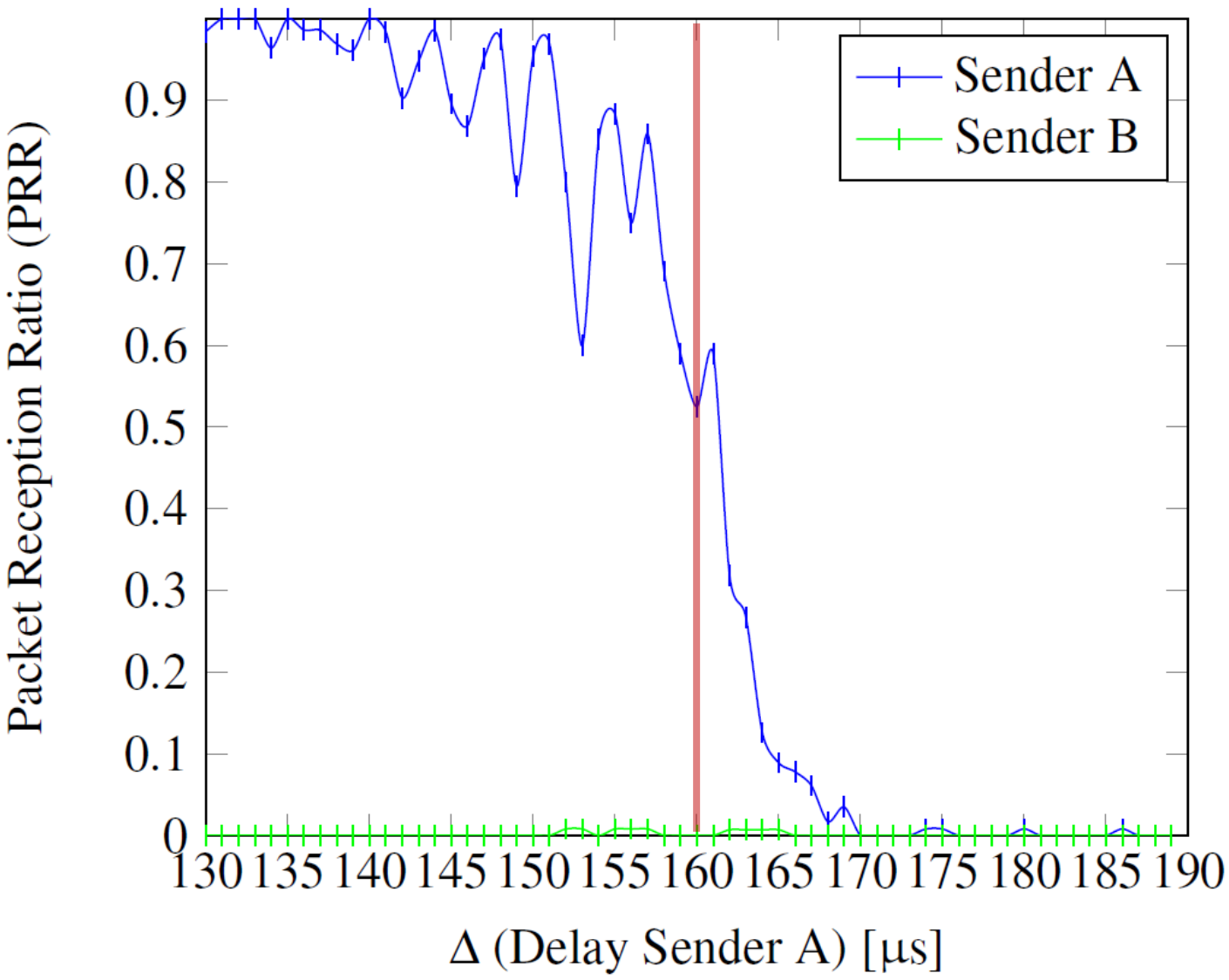
The Capture Effect – Packet Timing



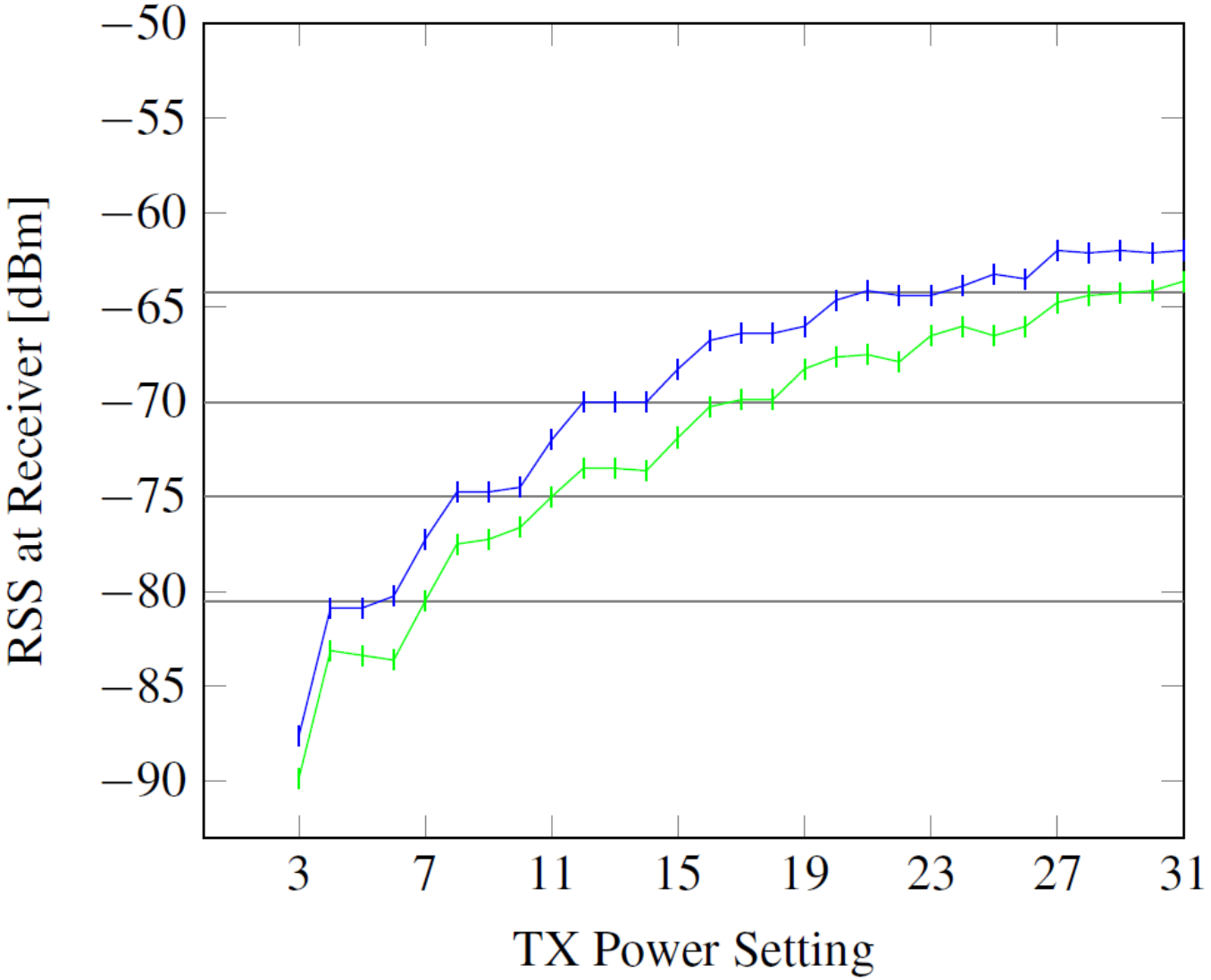
The Capture Effect – Packet Timing



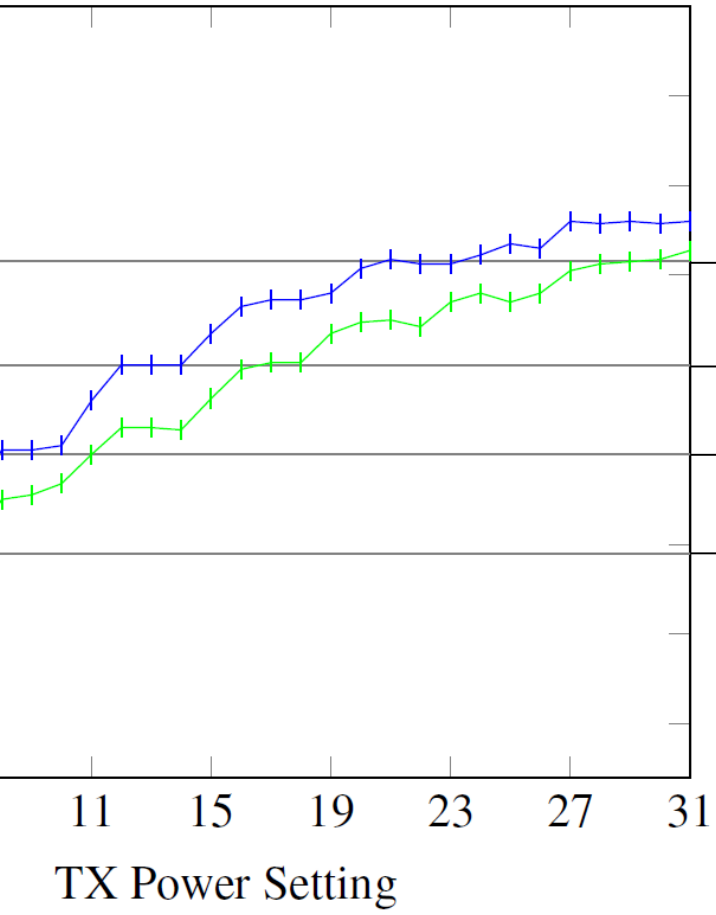
The Capture Effect – Packet Timing

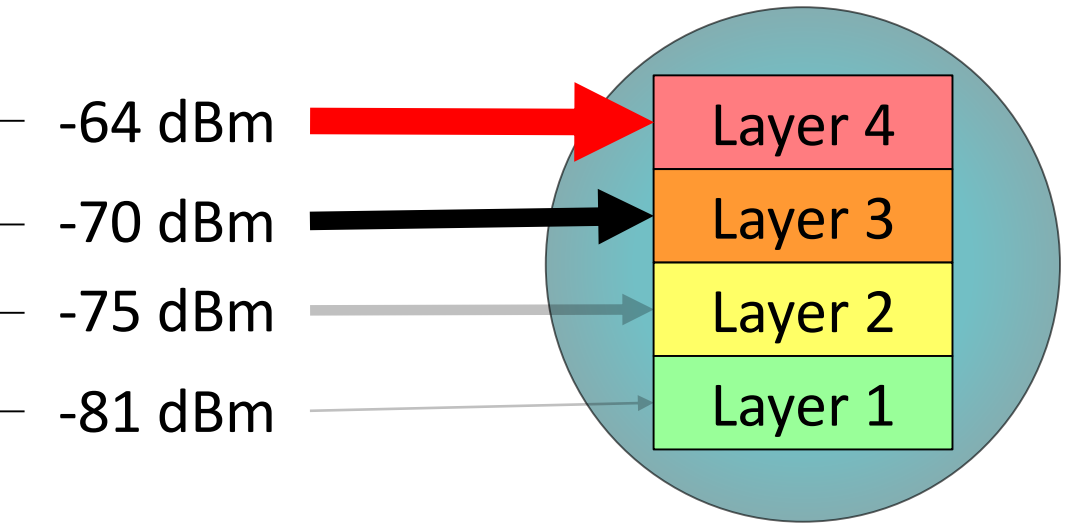


Prior Work: Protocol Layering



Prior Work: Protocol Layering

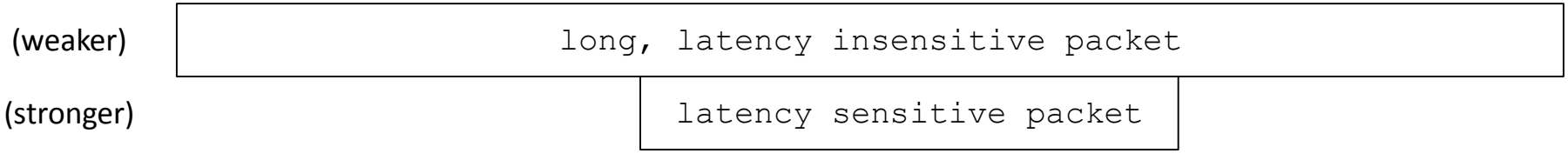


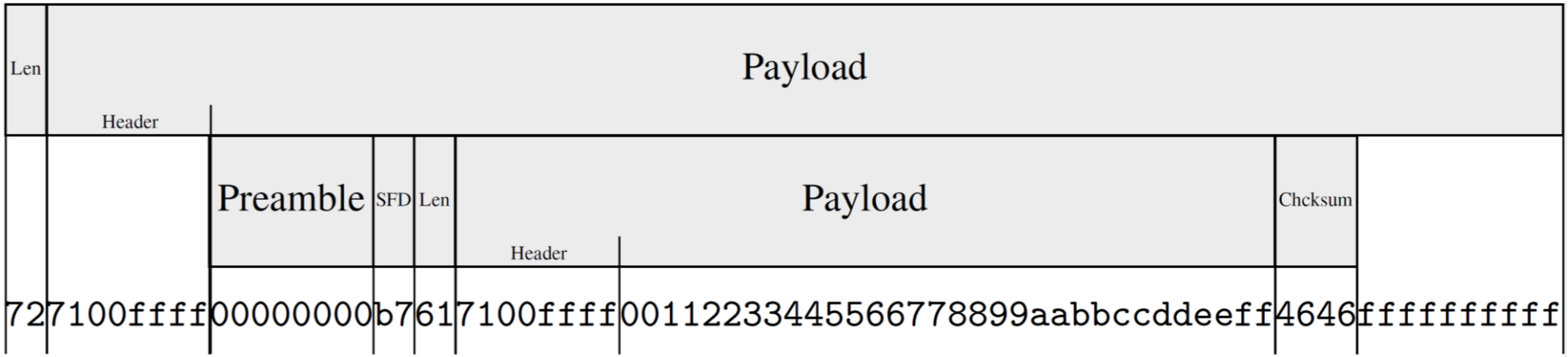


This work: going one step further …

- … beyond the granularity of packets!

Injecting into Longer Packets





Naïve Injecting

```
727100ffff22222222d10313229999223345566770011aabbccddeeff889960600ff3ffcfcf
727100ffff11111111c0720211888811223345566770099aabbccddeeff885757fffffffff
727100fffff77777777a6506077eeee7700112233445566ff8899aabbccddee3535fffffffff
727100fffff6666666595475766dddd6677001122334455eeff8899aabbccdd2424fffffffff
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727100fffffd4d4414d03703ed4b2b74d09112b338452f3596179657bec3ab93b35fffffffff
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727100fffffeeeeeeee1f9cacee7552eecc88e9aa88f9dd6644006127334455acacfffffffff
727100ffffddddddddfb9fedd8b88ddefff8d99a8bbfff8794a5ddecff889b9bfffffffff
727100ffff22252522b7637f22f33332a644556657667bb12e6664e01604f366d6fffffffff
727100fffff66868666219e5b66b7b86550a1d800f1ee30eed5b7cb8279617eb209fffffffff
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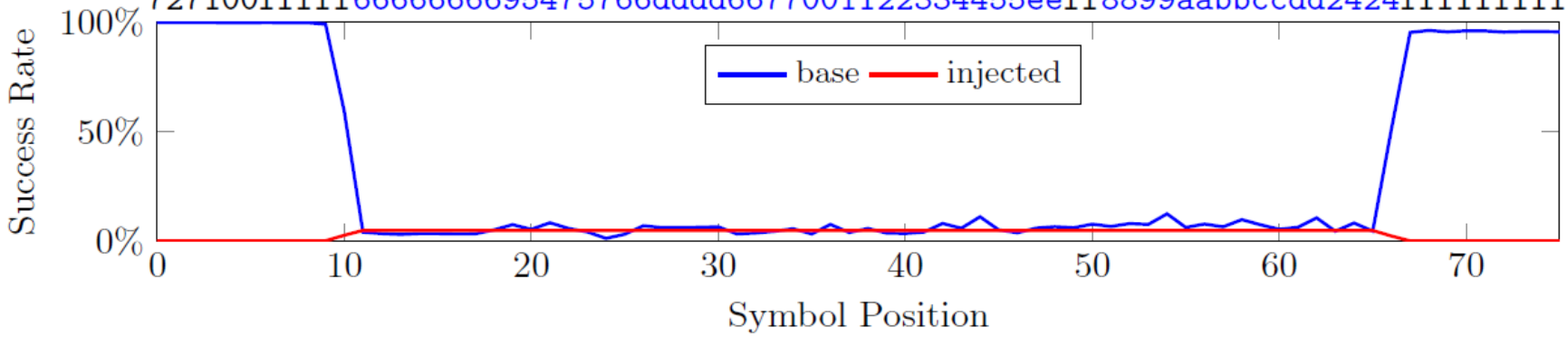
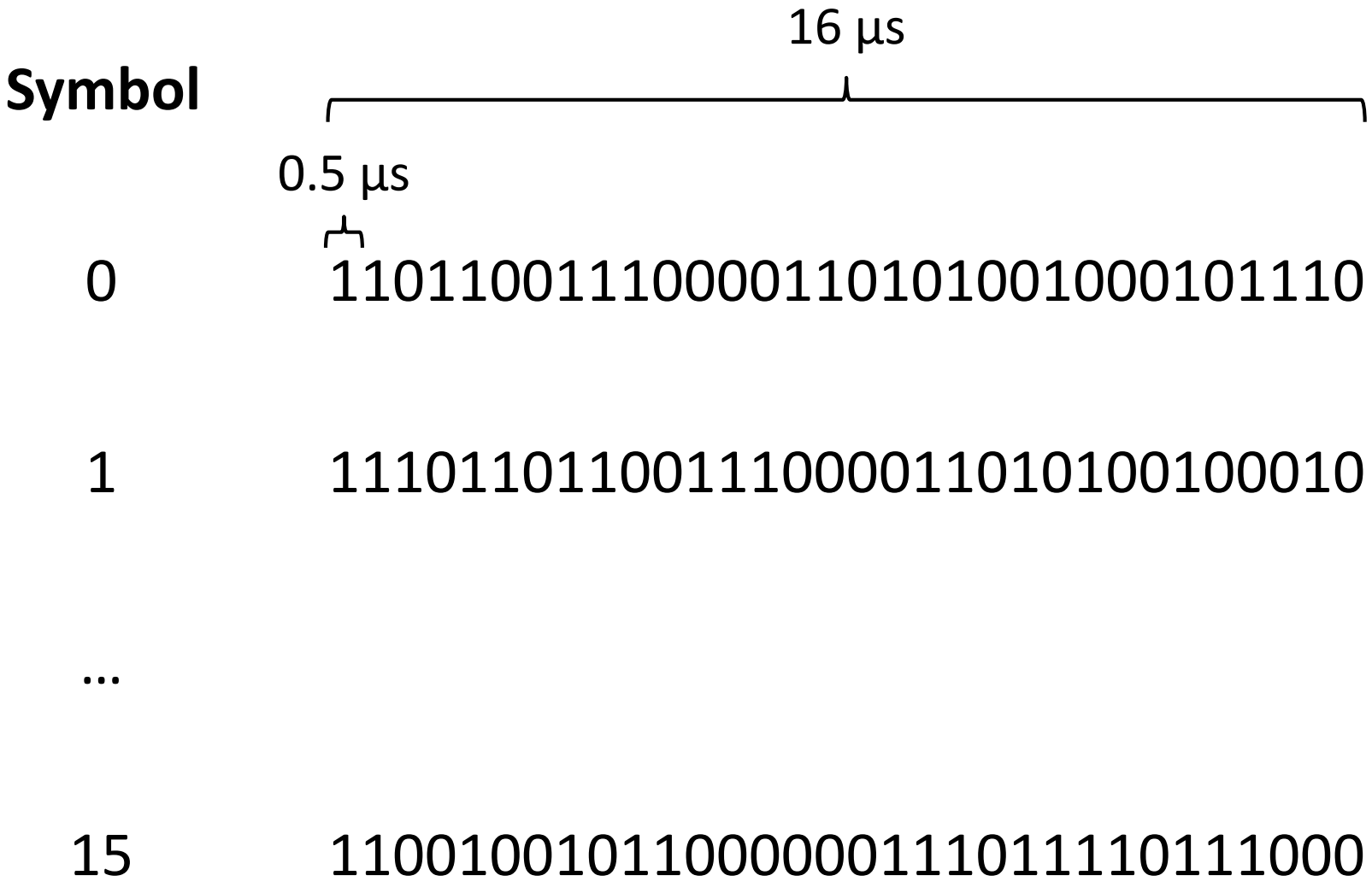


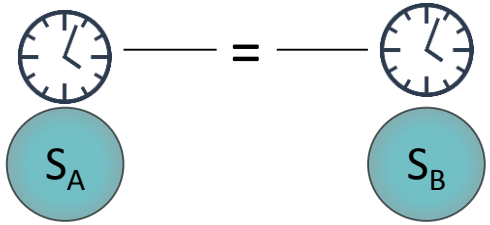
Chip Sequences in IEEE 802.15.4



Improving Symbol Alignment

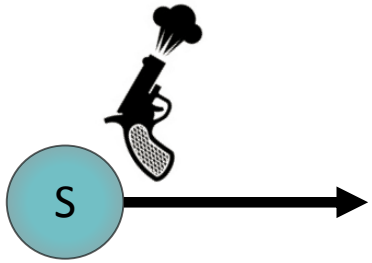
- TelosB clock: 4 MHz, but not stable

- Error Sources:
  - Clock synchronization



< 0.25 µs (75%)

  - Transmission timing



< 0.25 µs

  - Travel time

< 0.033 µs

Improved Symbol Alignment

727100ffff00000000b7617100fff00112233445566778899aabbccddeeff4646ffffffffff
727100ffff00000000b7617100fff00112233445566778899aabbccddeeff4646ffffffffff
727100fffff4e444442a756c44eeee44e5667ebc0b1cf3cc6deef634839a7e60f0ffffffffff
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727100ffff33333333e2142433aaaa3344556677000122bbccddeeff8899aa7171ffffffffff
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727100ffff00000000b7617100fff00112233445566778899aabbccddeeff4646ffffffffff
727100ffff00000000b7617100fff00112233445566778899aabbccddeeff4646ffffffffff
727100ffff4e4e44442a75fc442eee44e56677d00112f3cc6deefff8899abbb0222ff5ff9cfc
727100fff55555555584366555cccc5666770011223344deeeff8899aabbcc1313ff66fffff6
727100ffff00000000b7617100fff00112233445566778899aabbccddeeff4646ffffffffff
727100ffff5555555b476f6557ccc5566177001122334deeeff8899aabbcc1313ffffffffff
727100ffff66666665954757 66dddd6677001122334455eeff8899aabbccdd2424ffffffffff
727100ffff00000000b7617100fff00112233445566778899aabbccddeeff4646c595c555cc
727100ffff00000000b7617100fff00112233445566778899aabbccddeeff4646ffffffffff
727100ffff11111111c0720211888811223345566770099aabbccddeeff885757ffffffffff
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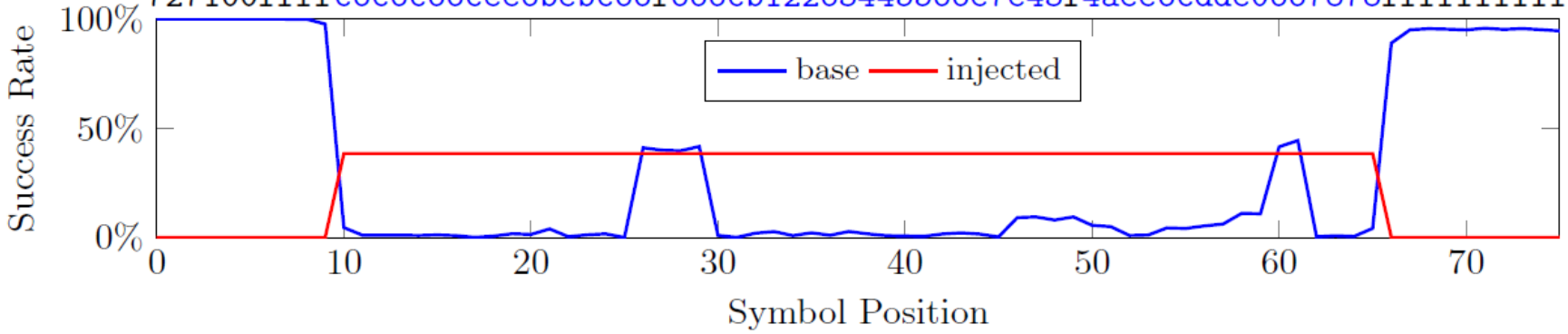

Symbol Descrambling

- Repairing Mapping

$$m(s, a) = s - (s \bmod 8) + ((s + a) \bmod 8) \text{ for } 0 \leq a < 8$$

Symbol Descrambling

Interpret 4 chips late

	00	11	22	33	44	55	66	77	88	99	aa	bb	cc	dd	ee	ff
0	16	18	20	20	20	18	16	0	12	14	20	20	20	14	12	16
1	0	16	18	20	20	20	18	16	16	12	14	20	20	20	14	12
2	16	0	16	18	20	20	20	18	12	16	12	14	20	20	20	14
3	18	16	0	16	18	20	20	20	14	12	16	12	14	20	20	20
4	20	18	16	0	16	18	20	20	20	14	12	16	12	14	20	20
5	20	20	18	16	0	16	18	20	20	20	14	12	16	12	14	20
6	20	20	20	18	16	0	16	18	20	20	20	14	12	16	12	14
7	18	20	20	20	18	16	0	16	14	20	20	20	14	12	16	12
8	12	14	20	20	20	14	12	16	16	18	20	20	20	18	16	0
9	16	12	14	20	20	20	14	12	0	16	18	20	20	20	18	16
a	12	16	12	14	20	20	20	14	16	0	16	18	20	20	20	18
b	14	12	16	12	14	20	20	20	18	16	0	16	18	20	20	20
c	20	14	12	16	12	14	20	20	20	18	16	0	16	18	20	20
d	20	20	14	12	16	12	14	20	20	20	18	16	0	16	18	20
e	20	20	20	14	12	16	12	14	20	20	20	18	16	0	16	18
f	14	20	20	20	14	12	16	12	18	20	20	20	18	16	0	16

Symbol Descrambling

Interpret 6 chips late

	00	11	22	33	44	55	66	77	88	99	aa	bb	cc	dd	ee	ff
0	16	16	14	14	16	16	18	18	16	16	14	14	16	16	18	18
1	18	16	16	14	14	16	16	18	18	16	16	14	14	16	16	18
2	18	18	16	16	14	14	16	16	18	18	16	16	14	14	16	16
3	16	18	18	16	16	14	14	16	16	18	18	16	16	14	14	16
4	16	16	18	18	16	16	14	14	16	16	18	18	16	16	14	14
5	14	16	16	18	18	16	16	14	14	16	16	18	18	16	16	14
6	14	14	16	16	18	18	16	16	14	14	16	16	18	18	16	16
7	16	14	14	16	16	18	18	16	16	14	14	16	16	18	18	16
8	16	16	14	14	16	16	18	18	16	16	14	14	16	16	18	18
9	18	16	16	14	14	16	16	18	18	16	16	14	14	16	16	18
a	18	18	16	16	14	14	16	16	18	18	16	16	14	14	16	16
b	16	18	18	16	16	14	14	16	16	18	18	16	16	14	14	16
c	16	16	18	18	16	16	14	14	16	16	18	18	16	16	14	14
d	14	16	16	18	18	16	16	14	14	16	16	18	18	16	16	14
e	14	14	16	16	18	18	16	16	14	14	16	16	18	18	16	16
f	16	14	14	16	16	18	18	16	16	14	14	16	16	18	18	16

Symbols Descrambled

```
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727100ffff00000000b7617100fff00112233445566778899aabbccddeeff4646ffffffffff
727100fffff4e444442a756c44eeee44e5667ebc0b1cf3cc6deef634839a7e60f0ffffffffff
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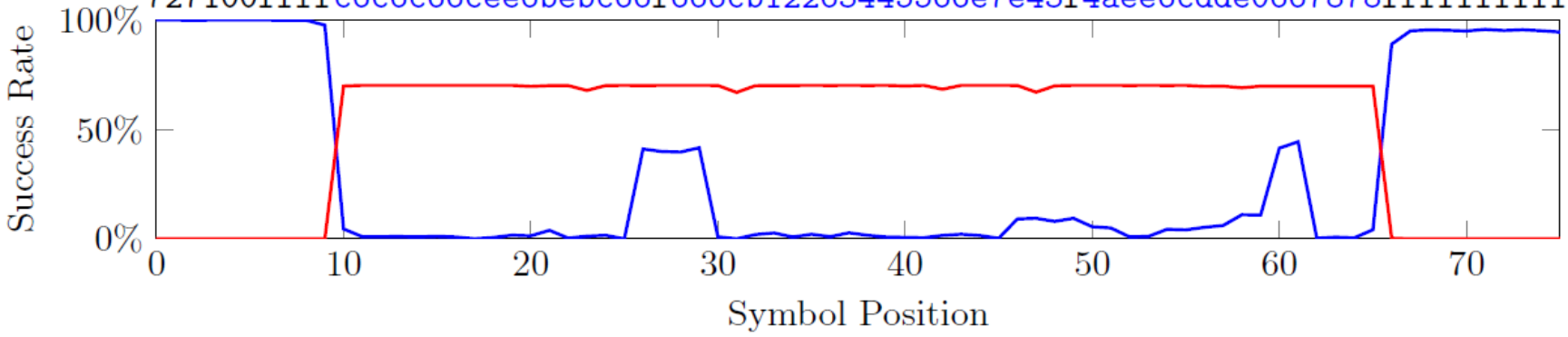
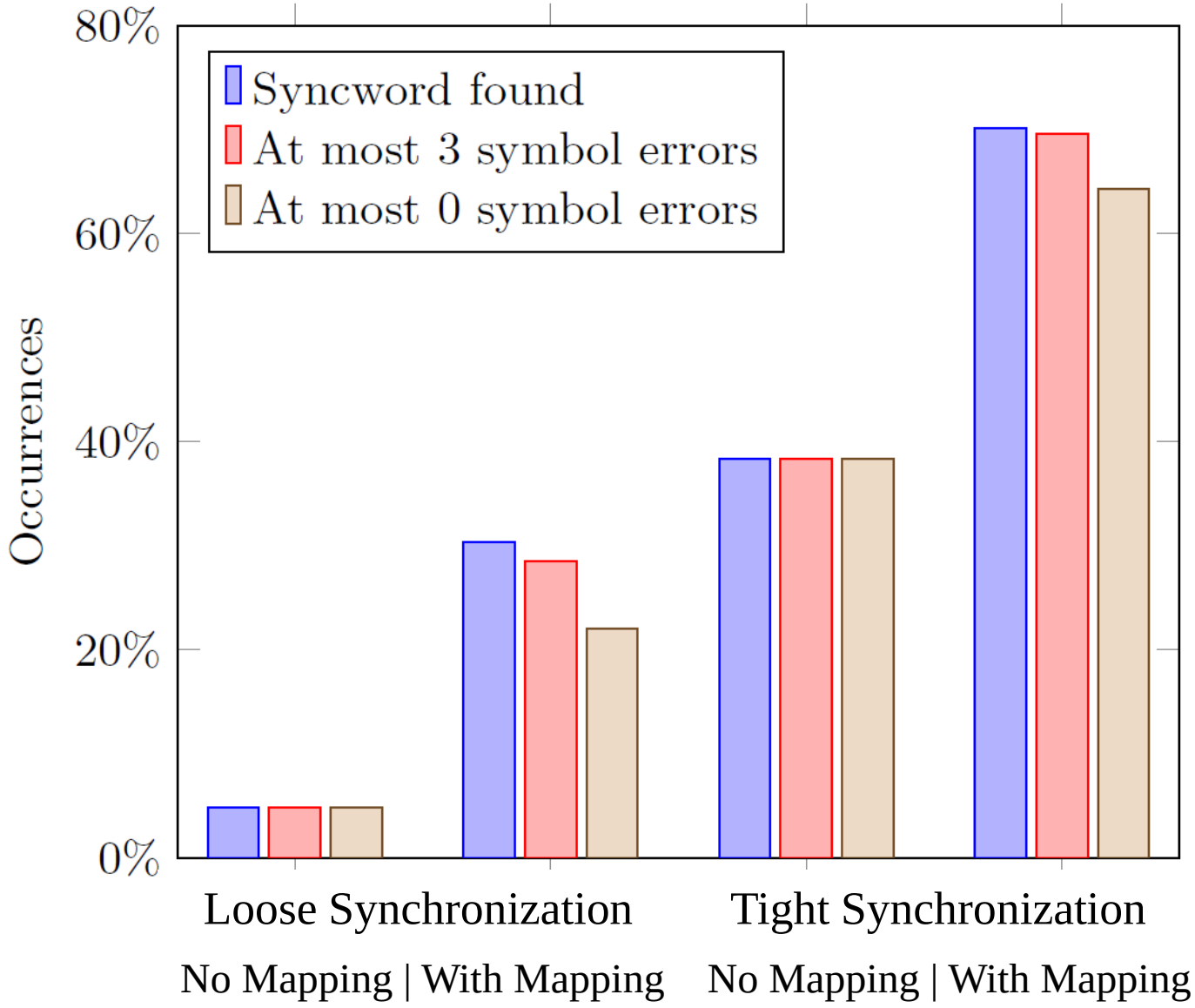


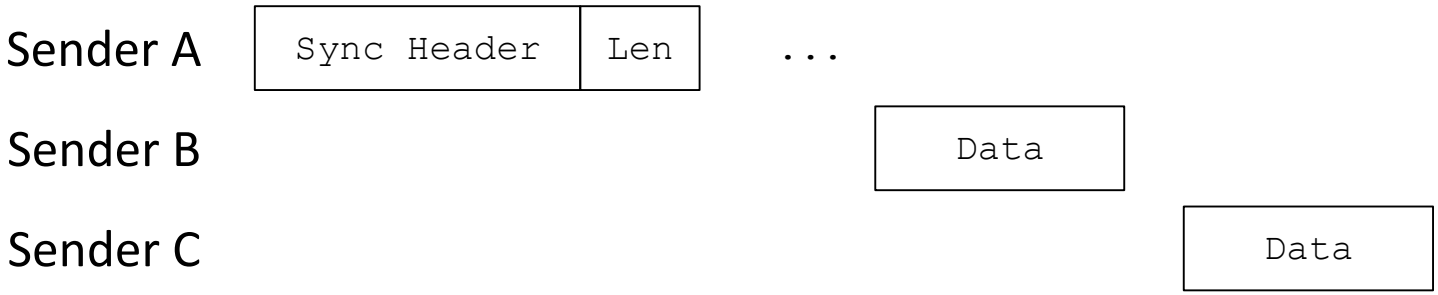
Overview Packet Injection



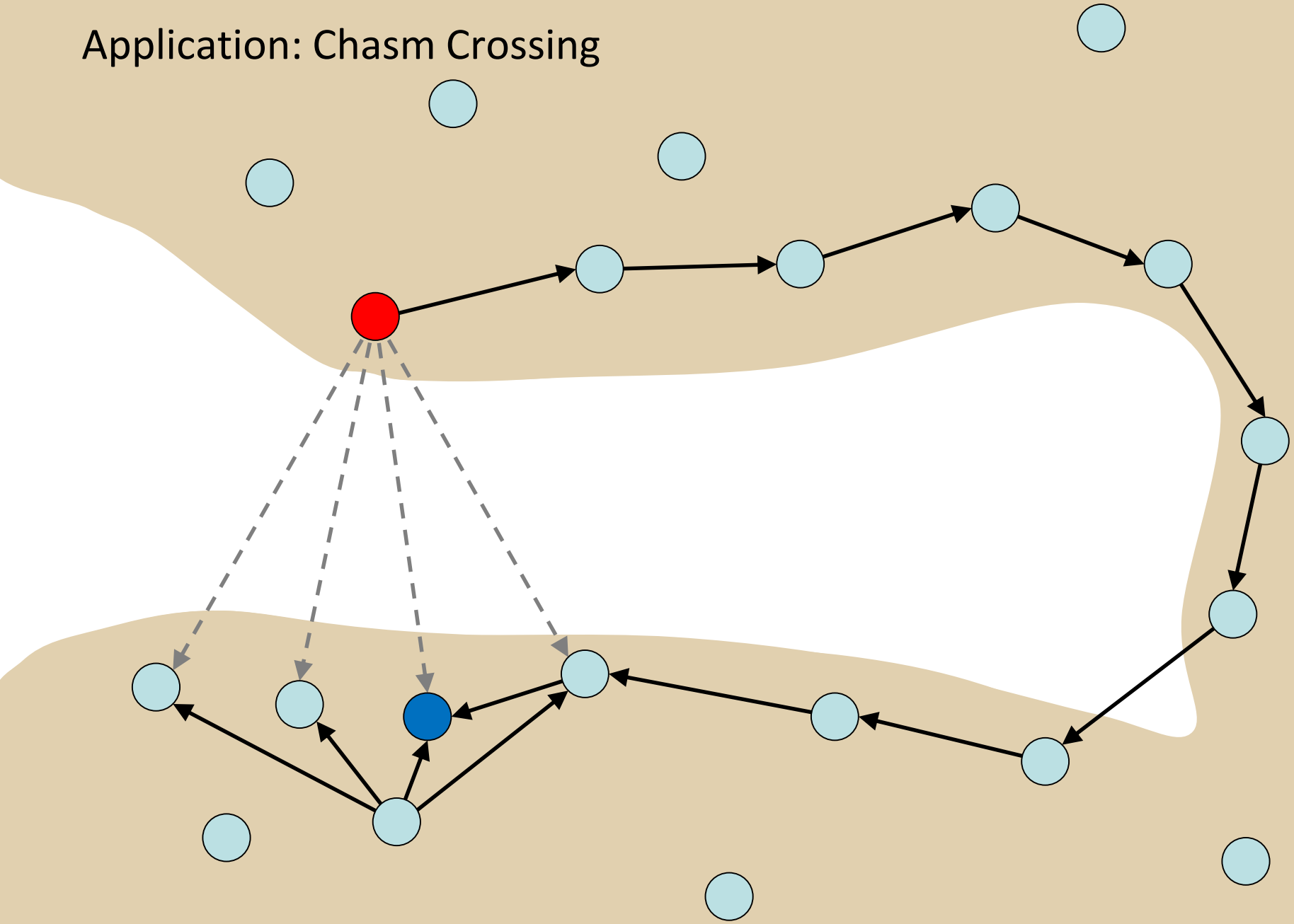
Generalized Result

We can decouple the synchronization header from the payload!

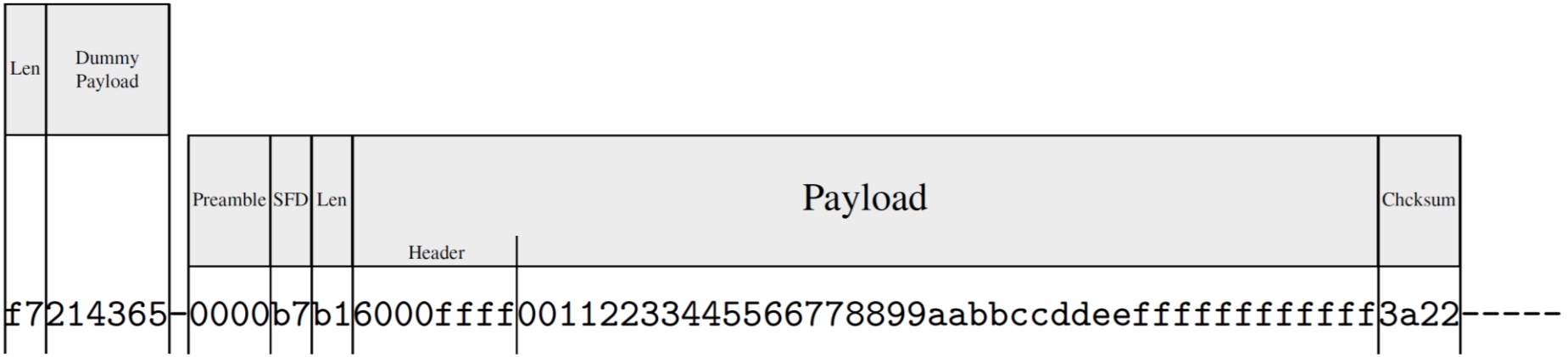
(for a price)



Application: Chasm Crossing



Wakeup Headers

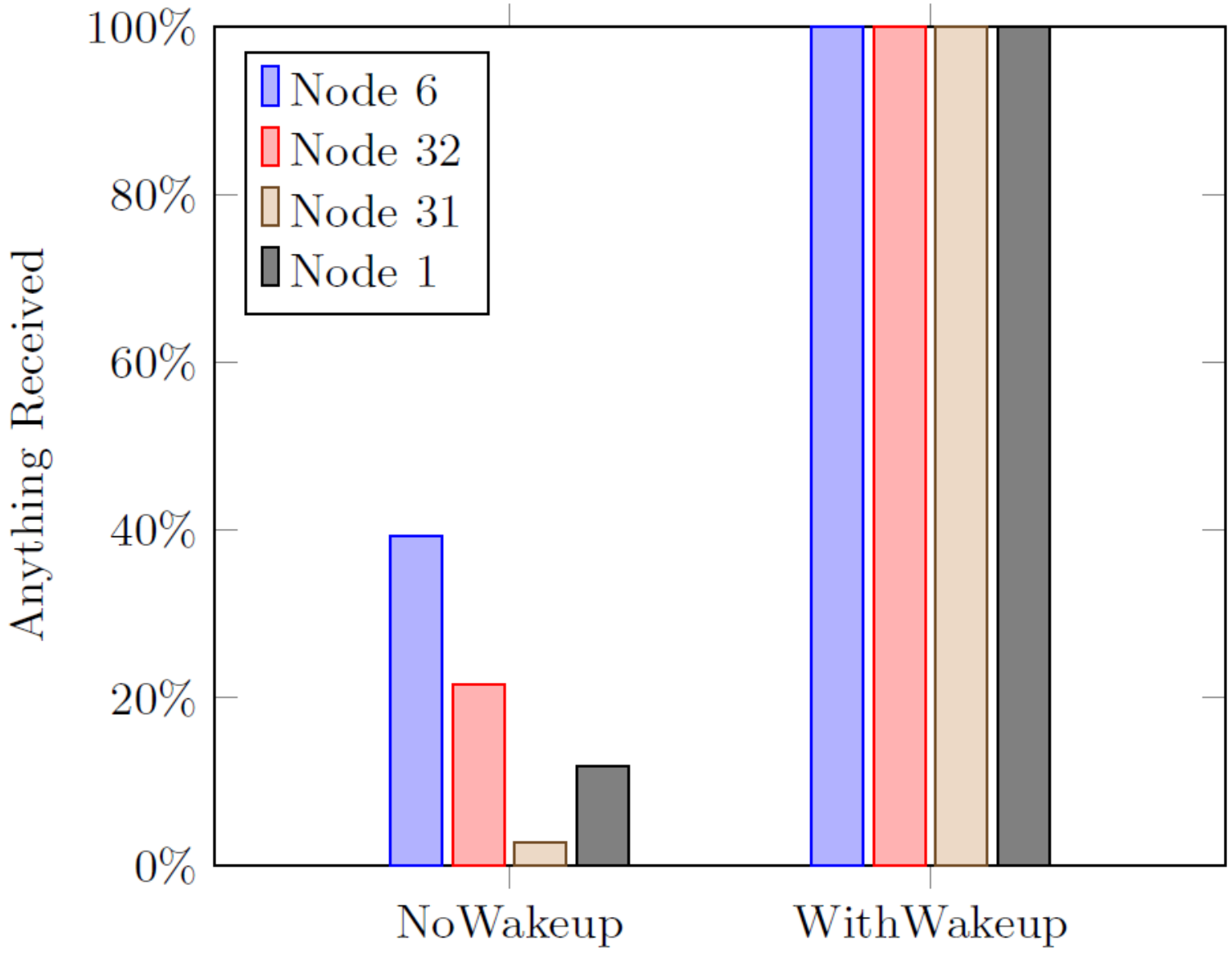


Combining Weak Packets

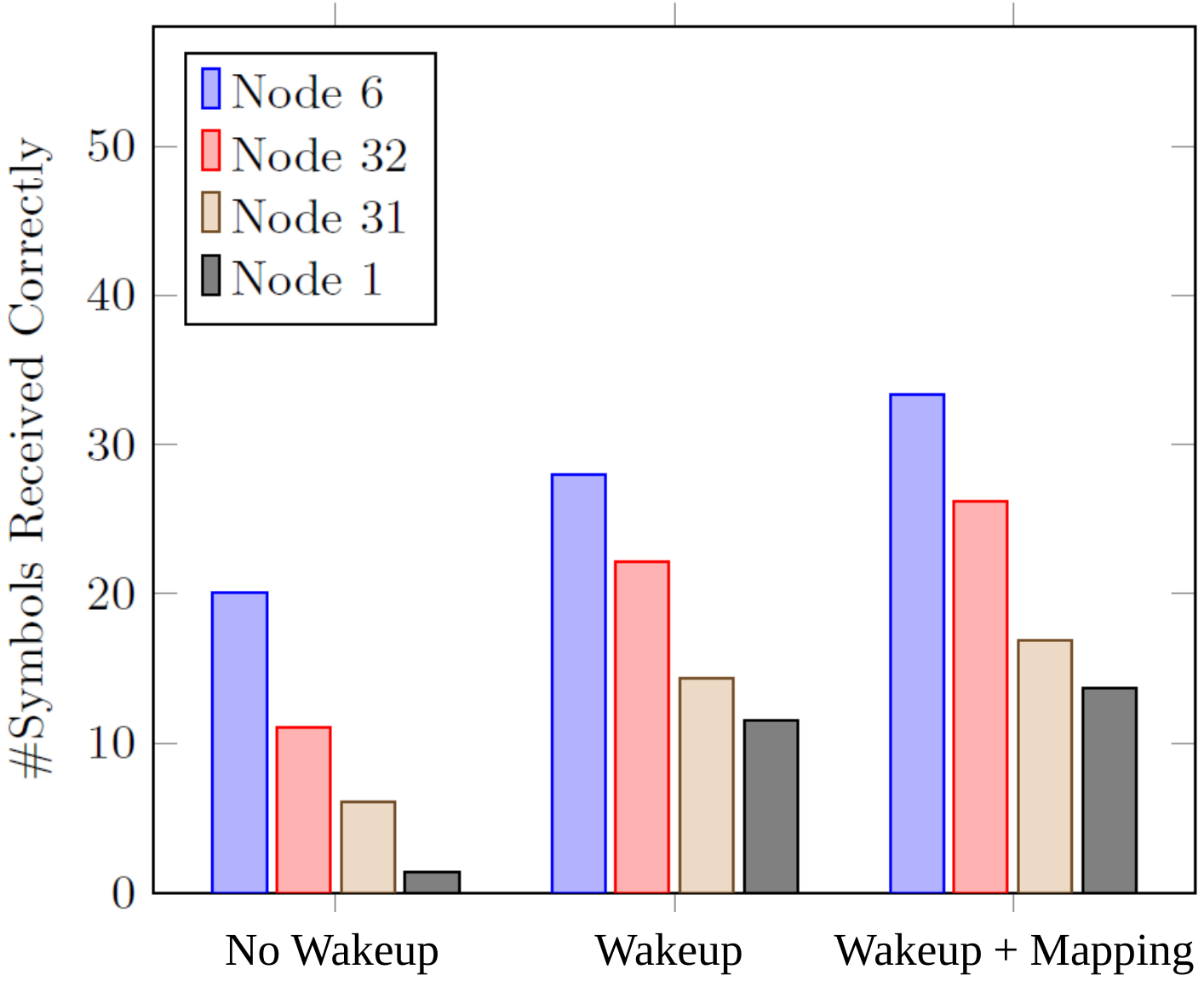
1b1f21ffdedededededededededededededededede

1b1f229fd3dedededededeeed2deddddedededededede8ede
1b1f21ffdeded4dedededededededededededededede
1b1f21ffde2ede1ed77eddd92ed2ded0deded7dede6e94

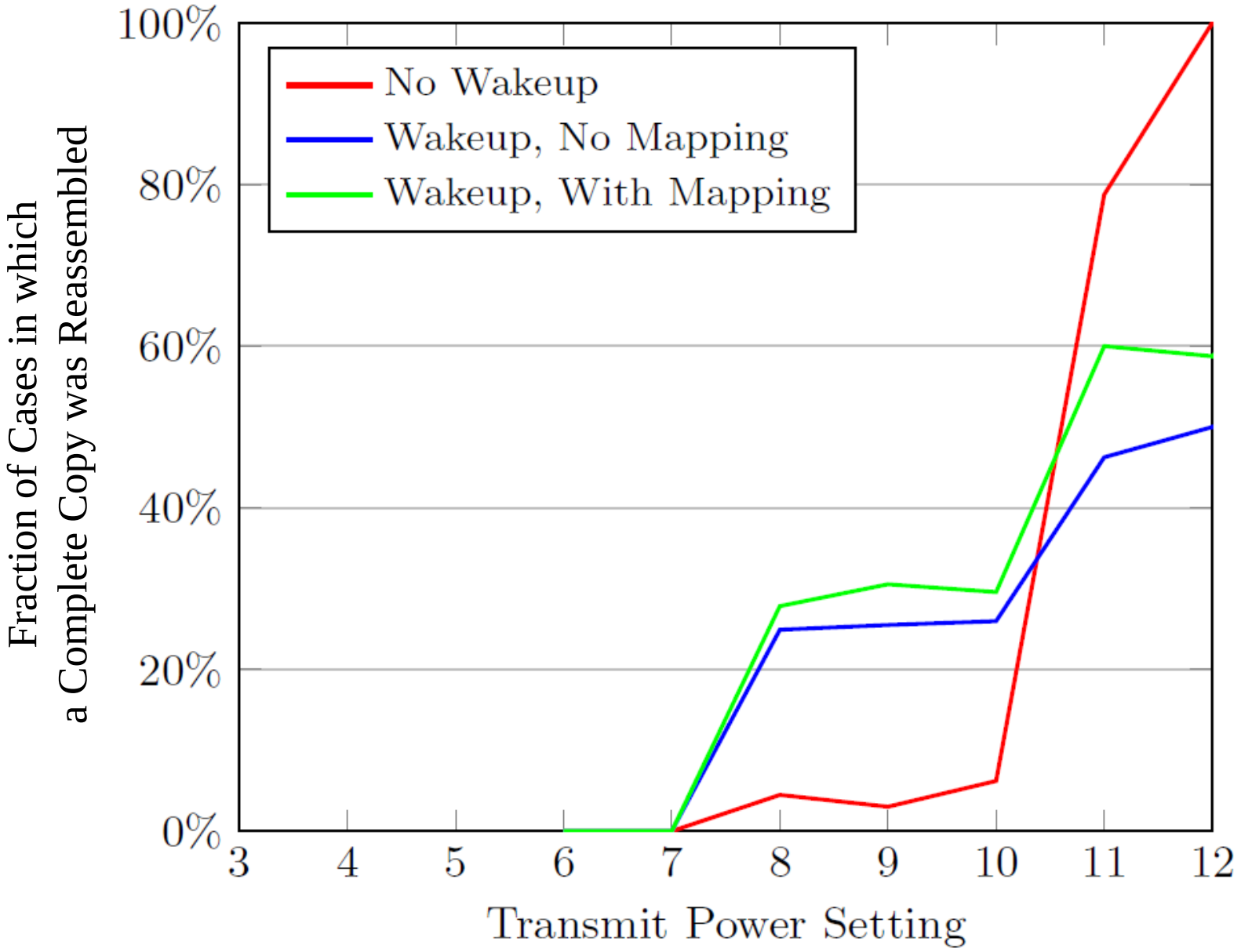
Chasm Crossing Results



Chasm Crossing Results



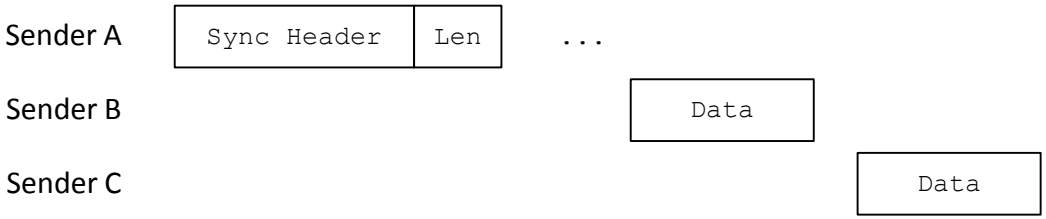
Chasm Crossing Results



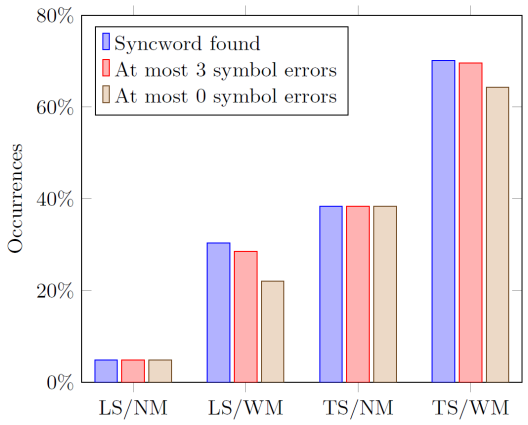
Future Work

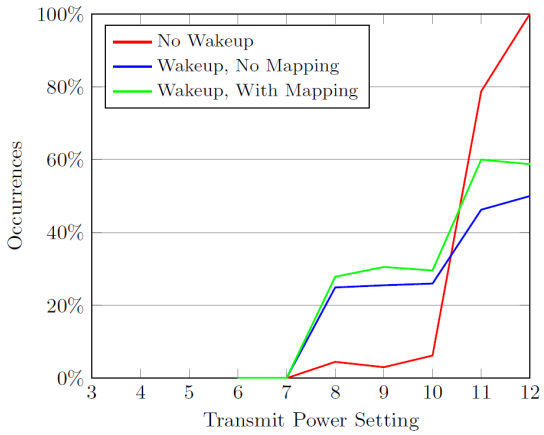
- Beyond proof of concept, integrate into MACs
- Transfer to other hardware and wireless specifications

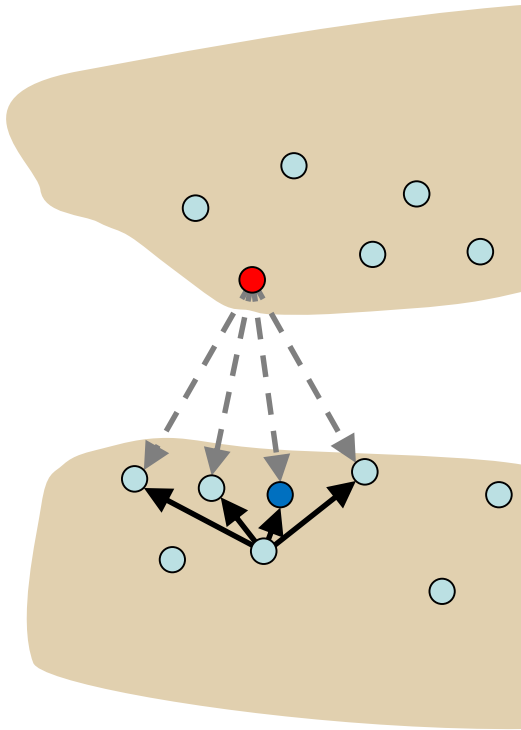
Summary



	00	11	22	33	44	55	66	77	88	99	aa	bb	cc	dd	ee	ff
0	16	18	20	20	20	18	16	0	12	14	20	20	20	14	12	16
1	0	16	18	20	20	20	18	16	16	12	14	20	20	20	14	12
2	16	0	16	18	20	20	20	18	12	16	12	14	20	20	20	14
3	18	16	0	16	18	20	20	20	14	12	16	12	14	20	20	20
4	20	18	16	0	16	18	20	20	20	14	12	16	12	14	20	20
5	20	20	18	16	0	16	18	20	20	20	14	12	16	12	14	20
6	20	20	20	18	16	0	16	18	20	20	20	14	12	16	12	14
7	18	20	20	20	18	16	0	16	14	20	20	20	14	12	16	12
8	12	14	20	20	20	14	12	16	16	18	20	20	20	18	16	0
9	16	12	14	20	20	20	14	12	0	16	18	20	20	20	18	16
a	12	16	12	14	20	20	20	14	16	0	16	18	20	20	20	18
b	14	12	16	12	14	20	20	20	18	16	0	16	18	20	20	20
c	20	14	12	16	12	14	20	20	20	18	16	0	16	18	20	20
d	20	20	14	12	16	12	14	20	20	20	18	16	0	16	18	20
e	20	20	20	14	12	16	12	14	20	20	20	18	16	0	16	18
f	14	20	20	20	14	12	16	12	18	20	20	20	18	16	0	16







Questions

Michael König